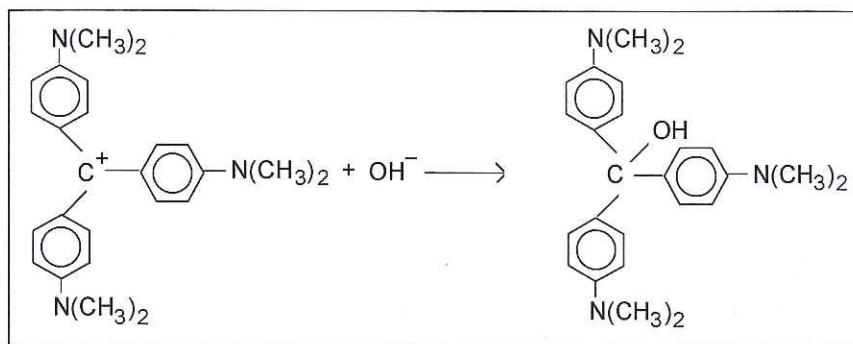


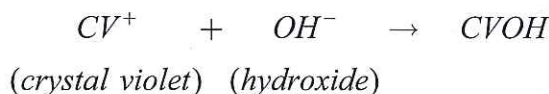
Rate Law Determination of the Crystal Violet Reaction

Background

In this experiment, you will observe the reaction between crystal violet and sodium hydroxide. One objective is to study the relationship between concentration of crystal violet and the time elapsed during the reaction. The equation for the reaction is shown here:



A simplified (and less intimidating!) version of the equation is:



The rate law for this reaction is in the form: $\text{rate} = k[CV^+]^m[OH^-]^n$, where k is the rate constant for the reaction, m is the order with respect to crystal violet (CV^+), and n is the order with respect to the hydroxide ion. Since the hydroxide ion concentration is more than 1000 times as large as the concentration of crystal violet, $[OH^-]$ will not change appreciably during this experiment. Thus, you will find the order with respect to crystal violet (m) and determine the pseudo rate constant k' which equals $k[OH^-]^n$ for each trial. Our rate law will be of the form

$$\text{rate} = k'[CV^+]^m$$

$$k' = k[OH^-]^n$$

As the reaction proceeds, the violet-colored reactant, CV^+ , will be slowly changing to a colorless product. Using the green (565 nm) light source of a computer-interfaced colorimeter, you will monitor the absorbance of the crystal violet solution with time. Absorbance of crystal violet is proportional to its concentration (Beer's law). Absorbance will be used to calculate concentration of crystal violet. $[CV^+]$ will then be plotted three ways to determine the order of the reaction for CV^+ .

- $[CV^+]$ vs. time: A linear plot indicates a *zero order* reaction ($k' = -\text{slope}$).
- $\ln [CV^+]$ vs. time: A linear plot indicates a *first order* reaction ($k' = -\text{slope}$).
- $1/[CV^+]$ vs. time: A linear plot indicates a *second order* reaction ($k' = \text{slope}$).

The reaction will be then run a second time at a different concentration of hydroxide, OH^- . Using the data from the second trial a new pseudo rate constant, k'_2 , will be determined. The order of the reaction in OH^- will be determined by comparing the two rate constants as shown below.

$$\frac{k'_2}{k'_1} = \left(\frac{[OH^-]_2}{[OH^-]_1} \right)^n \Rightarrow \log \frac{k'_2}{k'_1} = n \log \frac{[OH^-]_2}{[OH^-]_1}$$

Once the order with respect to crystal violet and OH^- has been determined, you will also be able to find the specific rate constant, k ($= k'/[OH^-]^n$), and the half-life for this reaction for the first run.

TRIAL # 1 10.0 mL 0.02 M NaOH
 10.0 mL $2.0 \times 10^{-5} \text{ M CV}$

TRIAL # 2 10.0 mL 0.01 M NaOH
 10.0 mL $2.0 \times 10^{-5} \text{ M CV}$

$[\text{OH}^-]$ TRIAL # 1

$$M_1 V_1 = M_2 V_2 \rightarrow M_2 = \frac{0.02 \times 10.0}{20.0} = 0.01 \text{ M}$$

$$\boxed{[\text{OH}^-]_1 = 0.01 \text{ M}}$$

$[\text{OH}^-]$ TRIAL # 2

$$M_1 V_1 = M_2 V_2 \rightarrow M_2 = \frac{0.01 \times 10.0}{20.0} = 0.005 \text{ M}$$

$$\boxed{[\text{OH}^-]_2 = 0.005 \text{ M}}$$



$$RATE = k [CV^+]^m [OH^-]^n$$

$$RATE = k' [CV^+]^m$$

$$k' = k [OH^-]^n$$

$k' =$ PSEUDO RATE CONSTANT

$$k'_1 = k [OH^-]_1^n$$

$$k'_2 = k [OH^-]_2^n$$

$$k'_1 = \text{SLOPE FROM TRIAL \#1}$$

$$k'_2 = \text{SLOPE FROM TRIAL \#2}$$

$$k = \frac{k'_1}{[OH^-]_1^n} \quad \text{also} \quad k = \frac{k'_2}{[OH^-]_2^n}$$

THEREFORE

$$\frac{k'_1}{[OH^-]_1^n} = \frac{k'_2}{[OH^-]_2^n}$$

$$\frac{k'_1}{k'_2} = \frac{[OH^-]_1^n}{[OH^-]_2^n} \rightarrow \text{SOLVE FOR } n$$

$$K = \frac{k_1}{[\text{OH}^-]^m}$$

$$K = \frac{k_2}{[\text{OH}^-]^n}$$

CALCULATE K

THEN

$$\boxed{\text{RATE} = K [\text{CV}^+]^m [\text{OH}^-]^n}$$